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Agronomic Performance of Timothy Germplasm from Forage and Turf Sods under Two Harvest Managements

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ABSTRACT

Cultivated timothy (*Phleum pratense* L.) is an important grass for hay production in temperate North America. It is underutilized in management-intensive rotational grazing systems because of its poor persistence when frequently defoliated. The objective of this study was to compare families selected for forage yield under frequent defoliation, families derived from old turf sods, and cultivars for agronomic performance under frequent and infrequent harvest managements (four vs. two harvests per year). Forage timothy was generally superior to turf timothy for most traits. Forage selections averaged 9.4 and 4.9% higher forage yield compared with cultivars under infrequent and frequent harvest managements, respectively, indicating that selection for higher forage yield under frequent harvest improved forage yield under both harvest frequencies. There were differences among the four types of turf (golf course fairways and roughs, cemeteries, and lawn/roadways), but these differences were not closely related to mowing height or frequency, perhaps because of the small sample size. Some turf collections ranked high for net herbage accumulation under frequent harvesting, but most turf collections were also characterized by a high frequency of regrowth panicles under either or both harvest frequencies. Timothy germplasm from old turf sods may have value in developing new timothy cultivars with improved tolerance to frequent defoliation and efforts should continue to gather and evaluate collections from a range of turf types and locations.

TIMOTHY was the first cool-season forage grass introduced to North America by European colonists in the 18th century (Berg et al., 1996). It is the most important forage grass in Scandinavia (Jönsson et al., 1992) and has the longest history of formal breeding activity of all the cool-season grasses bred in both Europe and North America (Casler et al., 1996). Over 150 named cultivars have been bred in North America or imported from other countries (Alderson and Sharp, 1994; Lawrence et al., 1995; GRIN, Germplasm Resources Information Network, www.ars-grin.gov/npgs/, verified 16 Apr. 2005).

Timothy cultivars are well adapted to hay management practices on the basis of relatively infrequent harvests. Timothy reproduces vegetatively by corms, swollen culm bases just beneath the soil surface. Individual corms are biennial, so long-term persistence of timothy depends on continual production of new corms (Childers and Hanson, 1985). Frequent harvesting of timothy increases the number of dead corms per plant by up to 93% and decreases living corm mass by up to 29% (Peters, 1958). Harvesting frequently, up to three or four cuts per year, and season-long competition in a timothy–alfalfa (*Medicago sativa* L.) mixture reduces persistence of timothy cultivars (Casler and Walgenbach, 1990; Smith et al., 1973). Cultivars with earlier heading tend to be more persistent under frequent harvests, but earliness does not guarantee persistence (Casler and Walgenbach, 1990).

Partly because of the long history of breeding timothy in North America and perhaps because of its excellent reputation as a highly cold-tolerant grass for hay production, it has been extensively planted throughout the north-central and northeastern USA and eastern Canada. Urbanization, resulting in the sale and development of farmland, has led to the conversion of many timothy hay fields to turf sods, including lawns, golf courses, and cemeteries. Timothy plants survive in many of these turf areas, despite more than 35 yr of frequent mowing. Because of the genetic heterogeneity that exists within timothy cultivars and ecotypes, these remnant populations of timothy represent germplasm that may have undergone natural selection for tolerance to frequent defoliation.

Many factors contribute to changes in swards under grazing, including treading, manure and urine deposition, soil fertility, climate change, diseases, insects, and seed banks (Charles, 1964; Watkin and Clements, 1978). However, Watkin and Clements (1978) suggested that the frequency of defoliation may be the most important factor causing changes to plant populations and/or sward structure of pastures. The objective of this study was to evaluate and compare the agronomic performance of three types of timothy germplasm under frequent and infrequent harvest managements. The germplasm included timothy families derived from old turf sods, timothy families derived from plants selected for forage yield under frequent harvesting, and timothy cultivars.

MATERIALS AND METHODS

The germplasm for this study derived from three sources: forage selections, turf collections, and commercial cultivars. A total of 450 timothy plants were selected from 19 600 plants evaluated by Casler (2001), the entire population originating from 489 accessions that represented 23 countries. These plants were selected for high forage yield, low second-harvest panicle density, and survival for 3 yr (1994–1996) under a frequent-harvest management. In July 1997, plants were removed, split into four ramets, and transplanted into a polycross block in a randomized complete block design with four replicates at Arlington, WI. The crossing block was maintained weed free by the use of pre-emergence herbicides and hand weeding (Falkner and Casler, 1998).

In June 1996, timothy plants were collected from old turf

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sods at five sites: three old rural cemeteries, a lawn/roadway that received heavy and frequent traffic by vehicles and farm implements at the Arlington Agricultural Experiment Station, and Edelweis Country Club near New Glarus, WI (Table 1). The cemeteries were located near Marshalltown, IA; Barre, WI; and Four Corners, WI. The cemeteries and the lawn/roadway turf at Arlington were all moderately well maintained with frequent mowing, but minimal fertilization. Timothy plants were common in each of these sods, with a typical patch diameter of 10 to 15 cm. Edelweis Country Club was approximately 25 yr old at the time of sampling and had been established on an old timothy hay field. Timothy plants are fairly common in both fairway and rough turfs on several holes, with a patch diameter ranging from 0.2 to 1.0 m. Plants were collected from both turf types. All turf collections were raised in the greenhouse for approximately 1 yr, cloned into four ramets, and transplanted to individual replicated and randomized polycross blocks at Arlington in July 1997.

All plants were treated with pre-emergence herbicide for weed control and fertilized with 56 kg N ha^{-1} in early spring 1998. Seed was harvested from individual plants when most panicles had changed color from green to brown. Seed was dried, threshed, cleaned, weighed, and bulked across replicates for each polycross family. Families with insufficient seed for further testing were discarded, leaving a total of 340 polycross families to be tested (Table 1). Therefore, all turf and selected forage populations were also selected for seed production, although this selection was based on seed yield per plant, and the components of this trait (fertility, panicle number, seeds per panicle) were not measured.

Seeds of all polycross families and 13 commercial cultivars (Alexander, Climax, Erecta, Goliath, Heidemij, Hokushu, Itasca, Kunpu, Motim, Senpoku, Tiller, Timfor, and Toro) were planted in a randomized complete block design with four replicates at Arlington, WI, in April 1999. The soil type was Plano silt loam (fine-silty, mixed, superactive, mesic Typic Argiudoll). Seeding rates were computed for each polycross family and cultivar following a germination test made according to standardized procedures (Association of Official Seed Analysts, 1998). The seeding rate was 1000 PLS m^{-2}, representing an average seeding rate of approximately 3.9 kg ha^{-1}. Plots were 0.9 by 1.5 m and drilled with a five-row planter. Tiers of plots were separated by 0.9-m alleys seeded to a mixture of turfgrasses (*Poa pratensis* L., *Festuca rubra* L., and *Lolium perenne* L.). Seeding-year management consisted of three harvests without data collection to manage annual weeds and two applications of 56 kg N ha^{-1} in midsummer and early autumn.

The experiment was managed for two harvests per year in 2000 and 2001—late June, when most plots were fully headed, and late September. Plots were fertilized with 112 kg N ha^{-1} in early spring and after the first harvest. Plots were harvested with a flail harvester at a 9-cm cutting height and a bulk sample was used for dry matter determination and adjustment across the entire experiment. Panicle density of regrowth was determined before the second harvest by counting all panicles in a 0.1-m^2 quadrat for each plot. Leafspot, most likely caused by *Drechslera* spp., was rated before second harvest using a visual rating scale of 0 = no necrosis to 10 = leaves 100% necrotic. Ground cover was determined just after the initiation of new growth in early spring 2002 by placing a 50-square grid (15 by 15 cm squares) onto the plot and counting the number of squares containing timothy tillers (Vogel and Masters, 2001).

The experiment was managed for four harvests per year in 2002 and 2003—mid-May (before jointing), mid-June, mid-August, and late October. Plots were fertilized with 56 kg N ha^{-1} in early spring and after each of the first three harvests. Forage yield was determined from two rising-plate meter measurements, using an instrument that had been previously calibrated for forage yield prediction (Casler et al., 1998). Net herbage accumulation for the growing season was computed from the data collected at each individual harvest (Casler et al., 2001). All plots were harvested at a 9-cm cutting height immediately after taking the rising-plate meter measurements. Panicle density before the second harvest was determined as previously described. Ground cover was determined in early spring 2004 as previously described.

Table 1. Number of timothy clones included in seven polycross blocks and number of polycross families with sufficient seed for further testing.

Source of germplasm	Number of original clones	Number of polycross families
Arlington lawn–roadway	35	20
Edelweis fairway	15	6
Edelweis rough	15	3
Barre cemetery	15	6
Four Corners cemetery	20	12
Marshalltown cemetery	20	1
Forage selections	450	292

Regrowth percentage was computed for each plot in each year as the percentage of dry matter forage yield contributed by all harvests following the first harvest. Data were analyzed by analysis of variance in which the effects of harvest management, year, and population were fixed and the effects of replicate and family were random. The sum of squares for populations and cultivars were partitioned into a set of seven orthogonal contrasts. Genetic correlation coefficients among variables were computed according to Mode and Robinson (1959). Homogeneity of genetic correlation coefficients for forage selections vs. turf collections were tested for each pair of variables using a two-sample t test, on the basis of the variances of each correlation coefficient, as computed by Mode and Robinson (1959).

RESULTS AND DISCUSSION

Genotypic variation among families was significant for all variables. The family × year interaction, which was significant for forage yield, regrowth, and panicle density, was partitioned into family × harvest management and family × year/harvest management. The family × harvest management interaction accounted for 46.5, 53.0, and 90.9% of the overall family × year interaction for forage yield, regrowth, and panicle density, respectively, and was the only portion of this interaction that was significant. This result is consistent with results of Surprenant et al. (1993) who showed that cultivar × management interactions are common in timothy. All results were presented as means over years within harvest managements.

Forage types of timothy, including cultivars and selections, did not differ in forage yield from collections made in old turf sods for individual harvest managements (Table 2). However, the differences were sufficiently consistent that when the two managements were averaged together, forage timothy had an average forage yield 0.9% higher than turf timothy ($P = 0.07$), indicating that these turf-type timothy plants had relatively high forage yield potential. This observation is similar in direction, but lower in magnitude, to results from smooth bromegrass (*Bromus inermis* Leyss.) plants collected from long-term sods that had been maintained

Table 2. Means representing seven orthogonal contrasts among timothy families and cultivars evaluated for nine variables over four years at Arlington, WI.

Group or source of germplasm	n	Infrequent harvest: Forage yield	Regrowth	Panicles	Ground cover	Leafspot†	Frequent harvest: Forage yield	Regrowth	Panicles	Ground cover
		Mg ha^{-1}	%	Number m^{-2}	%		Mg ha^{-1}	%	Number m^{-2}	%
All forage types	305	9.50	30.9	54	88	4.82**	8.70	51.0	26	78**
Turf collections	48	9.37	31.6**	70**	91**	4.48	8.66	53.4**	45**	73
Forage selections	292	9.55**	30.9	55**	88**	4.81	8.73**	51.0	26*	77
Cultivars	13	8.73	32.1**	44	82	5.01*	8.32	51.3	22	81**
Golf course	9	9.50	31.0	80**	92	4.30	8.67	51.4	19	74
Lawns	39	9.35	31.8	67	91	4.53	8.66	53.8**	51**	73
Cemeteries	19	9.03	31.2	88**	90	4.42	8.58	52.9	22	76**
Field lawns	20	9.64**	32.4*	48	91	4.62	8.74	54.7**	78**	70
Golf fairway	6	9.39	30.4	73	92	4.50	8.80*	52.5*	25**	73
Golf rough	3	9.65	31.8	90**	92	4.00	8.49	49.9	11	75
North American	6	9.32**	32.7*	52**	87**	4.60	8.55**	51.2	26*	81
Overseas	7	7.87	31.1	33	74	5.63**	7.96	51.5	18	81
Europe	3	8.08*	29.8	19	87**	5.63	8.16*	52.9**	21*	78
Japan	4	7.35	34.0**	65**	43	5.63	7.48	48.0	10	89**

* Means within a pair were significantly different at $P < 0.05$.
** Means within a pair were significantly different at $P < 0.01$.
† Leafspot (*Drechslera* spp.) rating: 0 = no necrosis to 10 = leaves 100% necrotic.

under frequent mowing vs. no mowing (Casler, 2004). Turf timothy had 2.3 and 4.6% higher regrowth percentage than forage timothy under infrequent and frequent harvest managements, respectively. However, this was likely a result of the 29 and 75% greater regrowth panicle density for turf timothy under infrequent and frequent harvest managements, respectively. A high frequency of panicles in regrowth can be responsible for increased regrowth forage yield (Jönsson et al., 1992). Although significant, ground cover differences were small and inconsistent between the two harvest managements. Forage timothy had 7.0% lower leafspot reaction than turf timothy.

Selection for increased forage yield was highly successful, resulting in 9.4 and 4.9% higher forage yield of selections compared with cultivars under infrequent and frequent harvest managements, respectively (Table 2). These increases in forage yield were reduced when cultivars from outside North America were removed from the comparison (data not shown). Forage selections had 2.3% higher forage yield than North American cultivars, averaged across the two harvest managements (9.14 vs. 8.94 Mg ha^{-1}, $P = 0.01$). A previous study had shown that cultivars and breeding lines had a 10.3% superiority in forage yield compared with collections made from pastures or meadows, reflecting the overall progress achieved in the development of numerous timothy cultivars (Casler, 2001). The forage selections appear to represent a further improvement in forage yield, as indicated by their yield advantage over a group of cultivars that is representative of the cultivars evaluated in the previous study (Casler, 2001). Optimism associated with these gains is tempered by the observation that regrowth percentage was reduced by 3.7% under infrequent harvest management and regrowth panicle density increased 24 and 16% for the two harvest managements. Leafspot reaction was 4.1% lower for forage selections than for cultivars. As with the previous contrast, ground cover differences were inconsistent and positively associated with forage yield differences only under infrequent harvest management.

Differences among timothy collections from the four types of turf were generally small and inconsistent (Table 2), possibly as much related to the genotype of the founder populations as to the type of turf in which it was collected. Golf course collections had greater panicle density under infrequent harvest management, but far fewer panicles than lawn collections under frequent harvest management. This may represent a selection response to many years of consistent and frequent mowing in a relatively stable and static environment. Selection under the frequent mowing regime of a golf course may favor genotypes that do not tend to flower after the first few mowings of the season. Elimination or reduction in the tendency to flower would allow these plants to focus more of their energy reserves at producing new leaf area, new haplocorms, and new tillers, favoring asexual or vegetative fitness.

This relationship was not consistent with the differences in panicle density between fairway and rough collections, which were opposite to that expected if natural selection under more frequent mowing favors plants that are less likely to flower during regrowth (Table 2). This result suggests that this relationship is more complex than suggested above or that other factors may be involved in this relationship. Collections from cemeteries and golf course roughs produced the highest panicle density under infrequent harvest management, but collections from the lawn/roadway turf produced the highest panicle density under frequent harvest management, suggesting a negative genetic relationship for panicle density between the two management treatments. It is also possible that the extremely small number of fairway and rough collections and their origin on one golf course, may have magnified the founder germplasm effect, obscuring the true relationship between mowing frequency and panicle density, which might be discerned from a more extensive collection.

The inconsistency between panicle density for frequent vs. infrequent harvest managements was supported by the overwhelmingly large 90.9% contribution of the family × harvest management to the overall

Table 3. Genetic correlation coefficients among nine variables measured on 292 timothy polycross families from forage selections (above diagonal) and 48 timothy polycross families from turf collections (below diagonal), all evaluated for four years at Arlington, WI.

Variable†	FY-I	RP-I	PD-I	GC-I	LS	FY-F	RP-F	PD-F	GC-F
FY-I		0.39 ± 0.12	0.61 ± 0.11	0.42 ± 0.18	−0.28 ± 0.20	0.89 ± 0.07	−0.79 ± 0.11	−0.70 ± 0.09	−0.48 ± 0.16
RP-I	−0.39 ± 0.36		0.58 ± 0.10	0.07 ± 0.18	−0.23 ± 0.17	−0.06 ± 0.27	−0.27 ± 0.23	−0.21 ± 0.15	−0.21 ± 0.16
PD-I	−0.27 ± 0.51	0.41 ± 0.29		0.14 ± 0.13	−0.13 ± 0.13	0.60 ± 0.13	−0.61 ± 0.12	−0.52 ± 0.08	−0.08 ± 0.13
GC-I	−0.86 ± 0.17	−0.99 ± 0.01	−0.61 ± 0.13		−0.02 ± 0.28	0.60 ± 0.27	−0.35 ± 0.33	−0.16 ± 0.23	−0.61 ± 0.16
LS	−0.78 ± 0.27	−0.72 ± 0.21	−0.32 ± 0.19	0.09 ± 0.53		−0.21 ± 0.27	0.26 ± 0.24	0.28 ± 0.15	0.17 ± 0.17
FY-F	0.73 ± 0.47	−0.21 ± 0.62	−0.28 ± 0.29	0.88 ± 0.17	0.07 ± 0.55		−0.99 ± 0.01	−0.59 ± 0.21	−0.83 ± 0.12
RP-F	−0.30 ± 0.83	−0.26 ± 0.54	−0.22 ± 0.27	0.40 ± 0.60	0.82 ± 0.16	0.16 ± 0.43		0.94 ± 0.02	0.19 ± 0.16
PD-F	0.47 ± 0.44	0.05 ± 0.36	−0.50 ± 0.13	0.12 ± 0.44	0.43 ± 0.25	0.40 ± 0.23	0.95 ± 0.02		0.06 ± 0.13
GC-F	−0.68 ± 0.34	−0.68 ± 0.22	0.53 ± 0.14	0.52 ± 0.36	−0.17 ± 0.34	−0.24 ± 0.29	−0.49 ± 0.18	−0.56 ± 0.14	

† FY, forage yield; RP, regrowth percentage; PD, panicle density; GC, ground cover; LS, leafspot; I, infrequent harvest; F, frequent harvest.

family × year interaction. Genetic correlation estimates for panicle density between the two harvest managements were negative and significant for both forage selections and turf collections (Table 3). The biological relationship between these two traits was highly unusual—a nonlinear relationship in which a high frequency of families had low panicle density at one harvest management, but not the other, and very large frequency of families had low panicle density at both harvest managements (Fig. 1). Most of the turf collections had high panicle density under one or both harvest managements, occurring on or near the outer edge of the bivariate distribution. Cultivars showed a distinct clustering toward the opposite edge of the bivariate distribution, generally having low to moderate panicle density under both harvest managements. This suggests that plant breeders have made progress in reducing timothy flowering in regrowth harvests.

Cultivars bred in North America had 18.4 and 7.4% higher forage yield under infrequent and frequent harvest management, respectively, compared with cultivars bred overseas (Table 2). This result is consistent with similar observations made for orchardgrass (*Dactylis glomerata* L.) cultivars (Casler et al., 2000, 2001). European timothy cultivars were slightly superior to Japanese cultivars in forage yield (10% for frequent and 9% for infrequent harvest management), but both were inferior to North American cultivars. This demonstrates that selection and breeding for forage production traits leads to improved adaptation to local environments in which selection is practiced. While the European and Japanese cultivars may have relatively broad adaptation within their original target population of environments, they appeared to be less well adapted, as indicated by their relatively low forage yield, to the environment represented by southern Wisconsin. Conversely, the North American cultivars, which were bred under environmental conditions more similar to southern Wisconsin than to continental Europe and Japan, appeared to be well adapted at this location.

A portion of the forage yield advantage for North American cultivars may have been due to a higher regrowth panicle density compared with the other cultivars, observed under both harvest managements (Table 2). This was accompanied by a 5.4% advantage in regrowth percentage under the infrequent harvest management. North American cultivars also had 18% lower leafspot reactions than the other cultivars, suggesting that part of their adaptive difference may be due to better resistances to local diseases. The low forage yield potential of the Japanese cultivars may have been due to their low survivorship, as indicated by their extremely low ground cover measured under the infrequent harvest management (43% for Japanese cultivars vs. 87% for both the North American and European groups). The increase in ground cover of Japanese cultivars from 43% in spring 2002 to 88% in spring 2004 suggested that the more frequent harvest management may have promoted additional tillering, allowing these cultivars to recover from earlier losses of stand. More frequent defoliation generally leads to increases in tiller density of perennial grasses (Christiansen and Svejcar, 1988; Grant et al., 1988; Matches, 1992).

The genetic correlation structure was radically different for forage and turf populations (Table 3). Only 12 of 36 genetic correlation estimates were homogeneous between forage and turf populations—four of these exceeded twice their standard error for both populations (Table 3), while the other eight were all nonsignificant. The relationship between forage yield and ground cover

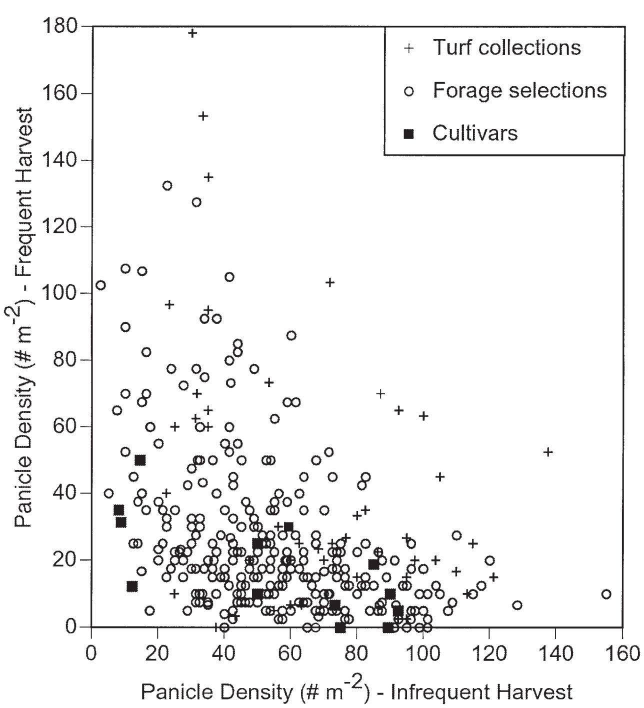

Fig. 1. Scatterplot of panicle density for frequent vs. infrequent harvest managements for 340 polycross families and 13 cultivars of timothy evaluated at Arlington, WI, for four years.

was complex. Ground cover under infrequent harvest management (GC-I) was positively correlated with forage yield under frequent harvest management (FY-F) for both forage and turf populations, perhaps as an artifact of the experimental design in which the frequent harvest management was imposed immediately after these ground cover measurements were made. Ground cover under infrequent harvest was correlated with forage yield under infrequent harvest management (FY-I)—positively for forage selections and negatively for turf collections. This suggests forage selections were less able to compensate for high tiller or plant mortality than turf collections. Conversely, turf collections with relatively low ground cover apparently compensated with larger and more massive tillers under infrequent harvest.

Regrowth panicle density was positively correlated with regrowth percentage, strongly for frequent harvest management and moderately for infrequent harvest management (Table 3). Because timothy stems result in higher dry matter yield, a higher panicle density results in higher forage yield for that harvest, resulting in greater dry matter partitioning to regrowth for those families with high regrowth panicle production. Jönsson et al. (1992) showed that selection for higher regrowth panicle density of timothy was highly effective for increasing season-total forage yield, largely by increasing forage yield of regrowth. These authors stated that little is known about the physiology or inheritance of this trait, although their results suggest the presence of additive genetic variation. Cocks (1958) also indicated that frequency of midsummer flowering varies among cultivars.

Although regrowth panicle density was negatively correlated between the two harvest managements for both populations (Fig. 1), regrowth percentage was not correlated between the two harvests. Changes in the frequency of harvest had a profound effect on regrowth dynamics of these timothy populations, resulting in differential genetic regulation of regrowth between the two harvest managements. Flowering, photoperiodism, tillering, and apical dominance are fundamental traits that regulate sexual reproduction and regrowth of perennial grasses. Timothy is an obligate long-day plant with no vernalization requirement for floral induction (Heide, 1982, 1989). Flowering of timothy occurs from late spring through midsummer and is regulated by high temperatures. Both the daylength requirement and the temperature threshold for flowering are under genetic control and are closely related to latitude of origin of timothy germplasm (Cooper, 1958; Heide, 1982). Many of the observed genotype × harvest management interactions for regrowth percentage and regrowth panicle density of timothy are most likely regulated, in part, by genes that control flowering, photoperiodism, tillering, and apical dominance.

Forage yield was positively correlated between the two harvest frequencies for both populations (Fig. 2), although this correlation coefficient was nonsignificant for turf collections because of the small number of turf-type polycross families (Table 3). The 26 highest ranked polycross families for forage yield under infrequent harvest (7.6% of the total) were all forage selections. However, turf collections made up five of the top 26 families when ranked for forage yield under frequent harvest. Despite the high positive genetic correlations, only seven families were in common between the highest ranked 26 families for forage yield under infrequent vs. frequent harvest management. Thus, there is considerable potential for differential selection responses between these two measures of forage yield. This is similar to results on orchardgrass, for which there was little correspondence in ranking of cultivars for forage yield

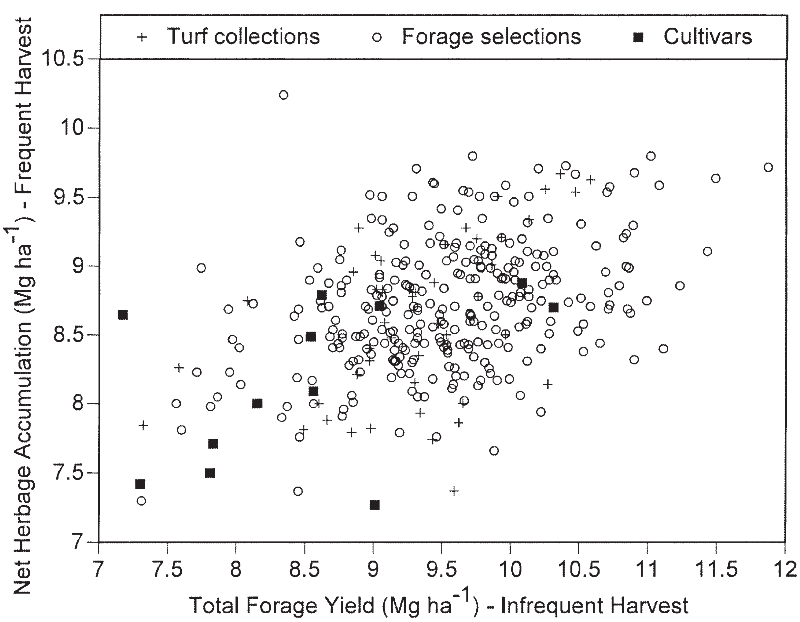

Fig. 2. Scatterplot of net herbage accumulation (NHA) for frequent harvest management vs. total forage yield (FY) for infrequent harvest management for 340 polycross families and 13 cultivars of timothy evaluated at Arlington, WI, for four years. One cultivar, with FY = 4.09 Mg ha^{-1} and NHA = 5.55 Mg ha^{-1}, was excluded from the figure to improve clarity.

under infrequent hay management with three cuts per year vs. management intensive grazing with five grazings per year (Casler et al., 2000, 2001). Selection for increased forage yield under infrequent harvest management is unlikely to result in optimal selection gains for a frequent harvest management or for management intensive grazing.

Timothy plants have a wide range of morphology (Jönsson et al., 1992), ranging from tall, erect, and early flowering (hay types) to short, prostrate, and late flowering (pasture types). Mixtures of the two types rapidly shift toward one phenotype or the other, depending on the frequency of defoliation (Charles, 1964). Natural selection acts as an adaptive strategy, favoring the more prostrate phenotype that possesses greater vegetative reproduction capacity under frequent defoliation (Warwick and Briggs, 1978). Grass swards have high mortality rates early in their life history (Charles, 1961), creating the potential for huge selection pressures, selection differentials, and selection responses which may be expressed in a relatively short time frame (Snaydon, 1978).

Phenotypic plasticity is another adaptive strategy that may be utilized in closely mown turf habitats (Warwick and Briggs, 1979). Plants that are capable of plastic responses will respond to close and frequent mowing with a more prostrate growth habit that will be expressed as long as they remain under that mowing regime. Upon removal from the closely mown habitat, these plants may be phenotypically similar to plants from other habitats. Phenotypic plasticity can mask genetic variability for adaptive morphological traits, limiting the effects of natural selection on a population in a habitat characterized by frequent defoliation (Bradshaw, 1965; Sultan, 1987). Turf timothy families that were phenotypically similar to forage timothy families were likely derived from populations that had undergone plastic adaptive responses to their environment.

Old turf sods appear to be a potentially valuable and unique source of timothy germplasm. The correlation structure among turf collections was more favorable than among forage selections for a breeding objective to improve forage yield under a frequent harvest management, combined with low regrowth panicle density, and high ground cover. Timothy germplasm from old turf sods should be more extensively sampled to provide more definitive information on the full extent of variability and the type of turf that has the greatest utility as a source of germplasm tolerant of frequent defoliation. A more extensive collection might also have utility in determining whether there is a relationship between turf habitat type and the predominant adaptive response of a population to its habitat (natural selection vs. phenotypic plasticity).

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